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Volta's English Connections

During the eighteenth century, the world of science changed in various important ways and definitively acquired a number of the features that have characterized it (and been taken very much for granted) ever since. I wish to focus here on two such features – neither one entirely new in the eighteenth century but both gaining an entirely new level of acceptance then – that had become well established by the 1760s, when the young Alessandro Volta was beginning his career, and that undoubtedly shaped the way he went about making his name.

First, while one might gain a reputation locally and even build a quite successful local career as a university professor or as a purveyor of experimental lecture-demonstrations, establishing a wider and more lasting reputation, now unequivocally depended upon making new scientific discoveries – that is, upon doing significant innovative research. This contrasts with the situation that obtained earlier in the century, when a number of people gained international scientific reputations almost entirely on the basis of their lecturing prowess. Simply doing good research was not, however, by itself, enough, any more than it has been at any other time in history. Research outcomes had also to be publicized. And by the end of the eighteenth century, even though refereeing protocols remained rudimentary at best, the journal article had become definitively established as the standard method of formally announcing new work, in preference to the older practice of publishing a monograph or treatise.

But which journal should one use? In Volta's day, it was already clear that some enjoyed a much higher standing and were much more widely disseminated than others, and that publication in a local journal, while sometimes retrospectively useful in establishing a priority claim, counted for very little so far as gaining wider recognition was concerned. Claimed discoveries had to be publicized more than locally, and had to be noticed by, and to withstand the scrutiny of, acknowledged experts in the field. In the eighteenth century, the weight of scientific authority came to be overwhelmingly (though never exclusively) concentrated in two centres – "centres of calculation", to use Bruno Latour's term[1] – namely Paris and London. Until work was weighed, acknowledged and taken seriously there, its status

[1] B. LATOUR, *Science in Action*, (Milton Keynes, 1987), chap. 6.

remained equivocal. The best way of achieving this was to have one's work discussed at meetings of the Académie Royale des Sciences in Paris and the Royal Society in London and then published under the aegis of one of these institutions. In Paris, throughout the eighteenth century the Academy's publications ran several years late. This gave journals such as the *Observations sur la physique*, founded in 1772 by the Abbé Rozier, quasi-official standing in announcing work presented to the Academy. In London, presentation of one's work at a meeting of the Royal Society, followed by publication in the Society's *Philosophical Transactions,* became the target to aim at, to ensure that the work would find its way into the wider discourse of science. To be noticed in other, widely-read publications – as many as possible – was also, of course, highly desirable.

How, though, were such things to be arranged? Historians writing about science in non-European parts of the world in the nineteenth and twentieth centuries – about "colonial science", as it is often called – have commented extensively on the "tyranny of distance", the effect on scientific practice, in a colonial environment, of isolation and distance from the major centres of scientific authority.[2] The problem of isolation was just as real for eighteenth-century practitioners, I wish to suggest, in relation to isolation from Paris and London, as it was for a colonial scientist working in, say, Australia, a hundred years later. There were practical problems – associated, for example, with the postal services of the time and also in many cases with working in languages other than one's own, now that Latin was no longer a *lingua franca* for scientific discourse – but, quite apart from these, it was never going to be an easy matter for an ambitious but completely unknown young scientist like Volta, working in Como or in Pavia, to gain a sympathetic hearing in either Paris or London. Somehow or other, he had to establish links with these centres of authority that would ensure that his work would be noticed. This was easier said than done! In this paper, I focus on how he went about establishing contacts in England and then exploiting them in order to bring his work to the centre of the scientific stage. In doing so, I shall also draw attention to features of the British scientific scene at the time that facilitated such contacts and thereby helped maintain and enhance London's position as a "centre of calculation".

Historians of colonial science have discussed other issues, too, that are of relevance here and that I intend discussing, in relation to scientists working at a distance from the metropolitan centres of science. The general theme of these is dependence – not only, as just described, on the intellectual authority of those at the

[2] G. BASALLA, "The Spread of Western Science", *Science*, 156 (1967), pp. 611-22; N. REINGOLD and M. ROTHENBERG, eds., *Scientific Colonialism: A Cross-Cultural Comparison*, (Washington, 1987); R.W. HOME, "The Problem of Intellectual Isolation in Scientific Life: W.H. Bragg and the Australian Scientific Community, 1886-1909", *Historical Records of Australian Science*, 6:1 (1984), pp. 19-30; D.W. CHAMBERS, "Does Distance Tyrannize Science?", in R.W. HOME and S.G. KOHLSTEDT, eds., *International Science and National Scientific Identity*, (Dordrecht, 1991), pp. 19-38.

centre but, more routinely, for the supply of up-to-date equipment and publications and the latest scientific news. Still other issues that historians of colonial science have discussed, relating to the small numbers of practitioners and inadequate resourcing of science common in the colonial setting, are less appropriate in considering Volta's situation, given the considerable interest in science in northern Italy during the Enlightenment and the almost unlimited funds made available to him for books and equipment, as part of Empress Maria Theresa's reconstruction of the University of Pavia.

There were numerous journals published in northern Italy at the time and Volta made extensive use of one of them in particular, Carlo Amoretti's *Scelta di opuscoli interessanti sulle scienze e sulle arti*, published in Milan; but beyond the Alps these did not have wide distribution or readership, and when Volta published in them, he could not rest content with doing that but had to take further measures to promote his ideas to the scientific community of northern Europe. Giuliano Pancaldi in his excellent thesis[3] has described some of the ways in which he did so, the principal means at his disposal being correspondence and personal contact accompanied by publication in France and England, whether or not the material had already been published in Italy. Pancaldi has also stressed how Volta's ambition to build a wider reputation in science fitted well with the desire of the Austrian authorities who ruled Lombardy at the time to parade their support for culture and learning, thus making it possible for him to obtain from them the backing he needed. The point is highly significant, since ways and means are as important in such situations as the will to act.

Volta's earliest attempts to establish a presence on the scientific stage are well known. As a callow eighteen-year-old, in 1763 he wrote to both Giambatista Beccaria in Turin and the Abbé Jean Antoine Nollet in Paris, setting out some ideas he had developed in relation to electricity.[4] Volta had not chosen his targets with any undue modesty, since both were among the world's leading electrical investigators at the time. Nollet had long been the acknowledged doyen of French "electricians", while Beccaria was the leading European advocate of the rival ideas of the American, Benjamin Franklin, that had sprung into prominence a decade earlier. Volta's attempt at thus breaking into the field from the top was not particularly successful, since neither Nollet nor Beccaria seems to have engaged seriously with his work at this time: Beccaria responded by prescribing a course of his own writings on electricity,[5] while Nollet made no move to bring Volta's ideas, very different from his own, to the attention of other Parisian scientists. Volta did, however, eventually elicit responses from Nollet as well as from Beccaria, and in

[3] G. PANCALDI, *An Enlightened Physicist: Alessandro Volta and Electricity, 1745-1827*, DPhil thesis, (University of Oxford, 1993).
[4] *VE*, I, pp. 33-4.
[5] *VE*, I, p. 37.

1767 the Frenchman arranged for a "petit volume" that Volta had requested to be sent to him.[6]

Yet the way Nollet went about doing this reveals very clearly the kinds of problems that must have confronted Volta as he tried to make his own work known. While letters were apparently by this time carried reliably enough through the mails, sending bulkier items, even something as simple as a book, was evidently not at all a straightforward matter. The best means Nollet could find offered a rather uncertain outcome. He would, he wrote, have done as Volta had apparently suggested and given the book to one of Volta's acquaintances, a Mr. Raimondi, to carry to Italy, except that he had already put it in an envelope and given it to one of the Parisian booksellers who had dealings with Italy, and who had undertaken to send it to Milan at the first opportunity; hence Volta should inquire there, in a month or so, of those who trade in French books, and he should be able to find the work!

1. The Priestley Connection

It was, however, intellectual engagement, not gifts of books, that Volta sought above all from the people to whom he wrote, and this he failed to gain from either Nollet or Beccaria. He had better luck when, a few years later, he wrote to Joseph Priestley in England, describing some electrical experiments he had performed. Priestley had first emerged on the scientific stage through the publication in 1767 of his highly successful *History and Present State of Electricity*, a work that Volta first came across in late 1771, probably in the form of the French translation published in Paris that year.[7] In his book, Priestley not only provided a wide-ranging survey of current knowledge in regard to electricity, he promised to incorporate in future editions any new discoveries that were communicated to him. Volta evidently found the invitation irresistible, even though he had been disconcerted to learn from Priestley's work that several discoveries that he had claimed as new were not, in fact, new at all; and he wrote to Priestley at once. Embarrassment similar to that felt by Volta has been all too common among those working at the scientific periphery, and difficulty in keeping up with what fellow scientists elsewhere are doing has long been recognised as one of the standard problems of "colonial" science. In Volta's case, he evidently told Priestley what had happened and the latter replied sympathetically, assuring Volta that he was not alone in having wasted time and energy repeating the discoveries of others. His own intention in writing his book, Priestley went on, was precisely to prevent such annoyances in future. Fortunately

[6] *VE*, I, p. 42. The volume in question was doubtless the just-published third volume of Nollet's *Lettres sur l'électricité*, (Paris, 1767).

[7] On 8 December 1771, Volta told Spallanzani that Priestley's *History* had come into his hands at the beginning of the autumn (*VO*, III, p. 77); from Priestley's letter to Volta of 14 March 1772 (*VE*, I, pp. 59-60), we learn that Volta had specifically mentioned the French translation of the *History* in the letter, now lost, to which Priestley was replying.

for Volta's pride, it appeared that he could continue to claim some discoveries as new; for these, Priestley assured him, he would be rendered justice in later editions of the *History*.[8]

The language used is significant here. Consistent with the naively empiricist view of science that Priestley promulgated in his *History*, it was new experimental discoveries that he looked for in Volta's work and that he undertook to give the Italian credit for, not his theoretical speculations. The friendliness of Priestley's letter and the prospect of publicity for his work were more than enough encouragement for Volta to persist with the correspondence, but the way in which he did so was also shaped by Priestley's initial response. A characteristic feature of Volta's later scientific communications was the way in which they were built around experimental innovations and eschewed elaborate theorizing. Structuring them this way was, I would suggest, something that Volta learned from his first exchange of letters with Priestley.

Priestley's first letter to Volta was dated 14 March 1772, and in late May of that year Volta wrote what was presumably a reply to this. Volta's letter no longer survives, but some years afterwards, in discussing his discovery of the electrophorus, he published, in Amoretti's journal, extracts from it in which he considered the differing degrees to which different substances were able to retain the Franklin-style electric fluid that he assumed underlay the various phenomena of electricity. Volta also sent Priestley copies of the two essays on electricity he had already published, *De vi attractiva ignis electrici* (1769) and *Novus ac simplicissimus electricorum tentaminum apparatus* (1771). It seems likely that he would have sent these at once, in order to be sure that Priestley would have them on hand whenever he began work on the next edition of his *History*; but again we see how uncertain the transmission of books could be at this period, for Priestley did not receive the package until some eighteen months later! Volta had entrusted it to a M. Guaita, who was presumably travelling to England. But when Priestley belatedly wrote on 10 November 1773 to thank Volta for sending the books, he explained that they had been delivered only that week: Guaita had passed them on to an Italian singer named Sandoli who had had them in his hands ever since. "It is very annoying", Priestley wrote, "that our literary communication should be so slow and so full of uncertainty". He was working on the next edition of the *History*, he said, but instead of inserting Volta's and other new discoveries in this, he intended describing them in the "Continuation" that he proposed to write. Unfortunately this scheme, and therefore the hopes that Volta had pinned on Priestley as a vehicle for publicizing his work, came to nothing. The reason is not hard to find. As Priestley went on to say in the same letter, he had himself done nothing on electricity for a long time. Instead, he had been spending his time investigating the properties of different kinds of air – the early stages, in fact, of the research that was soon to gain

[8] *VE*, I, pp. 59-60.

him scientific renown. Volta would find an account of this work, Priestley indicated, in the latest volume of the *Philosophical Transactions*.[9]

Volta evidently followed up the hint because in May 1774 he expressed doubts to Priestley about some of the ideas he had presented on fixed air.[10] However, the Italian continued to pin his hopes for scientific recognition on his electrical investigations, and on Priestley for publicizing these. Fortunately, the investigations were going well, and by mid-1775 Volta had an exciting discovery to report. This was the electrophorus, a device that seemed capable of functioning as an inexhaustible source of electricity: in the process, it challenged contemporary theoretical understanding by providing powerful support for Aepinus's denial of the existence of the supposed "atmospheres" of electric fluid surrounding electrified bodies and his introduction of a fully-fledged action-at-a-distance theory of electrostatic induction. Volta chose to announce his discovery of the device in an open letter addressed to Priestley, dated 10 June 1775, which was published in Amoretti's journal; a sequel including further experimental details was published in the same journal, later in the same year.[11]

Volta no doubt sent a copy of his letter to Priestley as soon as it was printed, or perhaps he sent a manuscript version even before this. Once more, he must have been grievously disappointed by the response, because it was not until almost a year later that he heard from Priestley. In the meantime, Volta must have written again, sending a copy of the sequel to his paper on the electrophorus and offering to prepare an Italian translation of Priestley's experiments on airs, because these are the matters to which Priestley chiefly referred in the letter dated 25 April 1776 that he eventually sent to Volta. It was probably shortly before this that Volta received his first acknowledgement from England of the initial paper announcing his discovery of the electrophorus. It came in the form of a copy of the recently published second volume of Priestley's *Experiments and Observations on Different Kinds of Air*, sent by someone of whom he had most likely never heard, Priestley's friend the Portuguese scientific enthusiast João Jacinto de Magalhães (Jean Hyacinthe de Magellan), who had been living in London since the early 1760s, in close touch with the latest developments in British science. On the fly-leaf of the book, there was a letter of explanation from Magellan: the book was sent, Volta was told, on Priestley's behalf, Priestley himself being so preoccupied with branches of physics other than electricity – the continuation of his work on airs, in fact – that he could not spare the time to write. The electrophorus experiment had been successfully repeated in England, Magellan reported. Priestley liked it and had asked Magellan to tell Volta this, since he himself was so busy with other things.

[9] J. PRIESTLEY, "Observations on Different Kinds of Air", *Philosophical Transactions*, 62 (1772), pp. 147-264.
[10] *VE*, I, p. 65. Once again, we do not have the full text of Volta's letter but only an extract from it that was published many years later.
[11] *VO*, III, pp. 93-108.

But, Magellan also remarked, the experiment seemed very like one already published years before by Wilcke and reported in Priestley's *History* – although, so Magellan allowed, Volta's device displayed to perfection the very remarkable phenomenon involved.

Magellan's note is undated but must have been written prior to Priestley's own letter to Volta of 25 April 1776, since it was evidently intended to serve as an interim acknowledgement from Priestley himself. Yet Volta probably did not receive it much before he received Priestley's own letter – indeed, it may even have arrived after Priestley's letter, because the latter included an apology for an unforeseen delay in sending Volta the book in which Magellan's message was inscribed: "I have been disappointed of an opportunity of sending you my *second volume* on air. It has been some time in the hands of a gentleman [presumably either Magellan or one of his agents] who was going abroad, but who has been prevented". Priestley repeated the news that Volta's electrophorus experiment had been tried successfully in England, and went on to complain again about the difficulties of communication: "It is much to be regretted that the correspondence of philosophers is so precarious and expensive".

While the lengthy delay before Volta received these letters from Magellan and Priestley would have been bad enough, their contents must have come as a double blow to him, scarcely compensated for by the gift copy of Priestley's book. As indicated above, Volta had already had the experience a few years earlier, when he first encountered Priestley's *History*, of finding that a number of things that he had thought were new discoveries he had made (and that he had published to this effect) had in fact already been made by others; now he was told that this also applied in the case his latest work, on which he had pinned great hopes. At the same time, he learned that the one good foreign contact he had was no longer greatly interested in the subject he was working on, and could scarcely spare him the time to write himself to say so. Volta's lifeline to the international scientific community seemed to have more or less collapsed! It was surely no coincidence that Volta himself took up the study of gases at this time. This, he had learned from the letters he had received, was where the action was!

As a result of Volta's switching his attention to the investigation of gases, he and Priestley again found interests in common and exchanged several further letters during the following few years. Soon after taking up the study of gases, Volta discovered a new kind of inflammable air associated with marshes – presumably methane – and Priestley found the account of this that Volta sent him in a letter dated 10 December 1776 of sufficient importance to include an extract from it in the third volume of his *Experiments and Observations on Different Kinds of Air*, published a few months later. Early in 1777, Volta published a book describing his observations.[12] Priestley acknowledged receiving a copy of this in a letter to Volta of

[12] A. VOLTA, *Lettere ... sull'aria infiammabile nativa delle paludi*, (Milano, 1777).

6 June of that year. In this same letter, Priestley also complained yet again about the difficulty and expense of maintaining a scientific correspondence. In the eighteenth century, a standard means of overcoming this was to arrange to have one's letters carried in the diplomatic mail, which was generally more reliable than the ordinary mails and was in addition paid for by the government concerned rather than by the recipient, as was otherwise the standard practice. Volta had by this time sufficiently aroused Priestley's interest in his work that, as Priestley reported, he was trying to arrange through Marsilio Landriani in Milan for Volta's parcels to be sent to him by this means (he seems to have been much less concerned about traffic in the other direction):

> I lament exceedingly that the correspondence of philosophical persons, living at a distance from each other, is so difficult and expensive; but there seems to be no remedy for it. I have desired Sig[r]. Landriani to endeavour to get letters, and small parcels, conveyed to one from you by means of the Imperial ambassador. If that could be done, it will save me a good deal of expence.[13]

A few months after this, in September 1777, Volta again chose to announce an important advance he had made, by means of an open letter to Priestley published in Amoretti's journal. On this occasion, he reported his development of an improved eudiometer with which he measured the "goodness" of different airs by observing the reduction in volume that occurred when a mixture of the gas in question and a determined amount of "inflammable air" [i.e. hydrogen] was fired by means of an electric spark.[14] A French translation prepared by Volta's friend, the Genevan physicist Jean Senebier, was published in Paris, in Rozier's journal, some months afterwards. A follow-up paper on the combustion of inflammable air, likewise drawn up in the form of a letter to Priestley, was also translated by Senebier and published in Rozier's journal, later in 1778.[15] Volta doubtless sent the originals of both letters to Priestley at the time he wrote them, and he evidently sent other letters to the Englishman as well, though these have not survived. How often letters travelled in the other direction is less clear, though a few clearly did. Thus in July 1778, in a letter to Landriani, Priestley gave news of his latest work on gases, which he asked Landriani to pass on to Volta.[16] Landriani did even better than this, he arranged for Priestley's account to be published in Italian translation in Amoretti's journal; when Volta wrote to Senebier on 10 October, it was from this source that he quoted the relevant passage.[17] In this same letter to Senebier, Volta also mentioned another letter, now lost, that Priestley had just written to him. Only one other letter

[13] *VE*, I, pp. 170-1.
[14] *VO*, VI, pp. 173-84. For the context of Volta's work, see J.R. PARTINGTON, *A History of Chemistry*, (London, 1962), III, pp. 321-7.
[15] *VO*, VI, pp. 185-215.
[16] *VE*, I, pp. 263-4.
[17] *VE*, I, pp. 287-8.

from Priestley to Volta is known, however, this being dated 5 August 1779. By this time Priestley was clearly relying on others and above all on Magellan, to keep up the contact. Priestley himself seems to have found the difficulties involved in maintaining the correspondence too much of a discouragement. Indeed in this letter he bemoaned once again: "I never think of you without lamenting the distance at which we are placed from each other, the tediousness of writing letters, and the expence and uncertainty of their conveyance ...".[18]

There can be no doubt that Volta drew enormous encouragement from his correspondence with Priestley, even though this was, as we have now seen, subject to considerable interruption. Priestley was the first person from the centres of scientific authority in England and France to take Volta's work seriously and he always managed to write to the young Italian in a friendly and positive way. Moreover, the correspondence blossomed just as Priestley was becoming a major figure on the international scientific scene. Volta, instead of exchanging letters with the otherwise unknown author of a very competent history of electricity, suddenly found himself in friendly contact with one of the leaders of the most exciting research programme of the age. Small wonder that he took up research in this new field himself! But Priestley was always extremely busy with his research and writing, not just on scientific matters but also in connection with the theological polemics in which he was constantly engaged; and so, even when Volta's work on gases actively captured his interest, Priestley found it difficult to find the time to write to him about it. Encouraging though the connection with Priestley was for Volta, he must also often have found the Englishman's long silences rather frustrating.

2. Magellan

Fortunately, Volta by this time had established a second line of contact with British science, through Priestley's friend Magellan. While this did not carry the same prestige as the link with Priestley himself – indeed, perhaps precisely because it did not – it was in many ways much more satisfactory from Volta's point of view. Whereas Priestley was constantly too busy to write, Magellan made it his business to write regularly. And when Volta needed information or equipment, Magellan went out of his way to supply it, as he likewise did to many other scientists scattered across the face of Europe. His remarkable career as a late-eighteenth-century "scientific agent", as exemplified in the relationship he established with Volta, is the second major focus of this paper.

We have already seen how Magellan in the first part of 1776 sent Volta, on Priestley's behalf, an inscribed copy of one of the latter's books. There are no personal greetings and no valediction of any sort in the note that Magellan wrote,

[18] *VE*, I, pp. 357-8.

which suggests that it represents his first contact with Volta. Soon afterwards, their interaction blossomed – most likely as a result of a follow-up letter from Magellan; it is much less likely that the initiative came from Volta, since he would have known nothing about Magellan beyond his name and the fact that he was a friend of Priestley's. Precisely how the relationship developed is not known, because evidence is lacking. By late 1778, however, Magellan was drawing funds against Volta's account with a Milanese banker with an office in London – a sure sign that he had been purchasing materials on Volta's behalf.[19] In all, eighteen letters from Magellan to Volta survive from the period 1776-85, plus one letter from Volta to Magellan.[20] It is clear that many other letters were written. All except the first of those that survive date from after Volta's appointment to the chair of experimental physics at Pavia; many of them, as we shall see, are chiefly concerned with the furnishing of apparatus to support Volta's research and lectures there. Unfortunately, it appears that none of this apparatus has survived.

Though Magellan's name has sunk into obscurity nowadays, he was well known in scientific circles in his own time. Born in the small fishing town of Aveiro, in Portugal, in 1722, he enrolled at the age of 11 in the Augustinian college at Coimbra and ten years later joined the Augustinian order. The Coimbra college had an excellent library, and Magellan developed strong scientific and philosophical interests. Eventually, having become dissatisfied with monastic life, in 1754 he was released from his vows with a papal letter of secularization. He was in Lisbon during the great earthquake of 1755, and afterwards seems to have undertaken a "philosophical tour" for several years. He spent some time in Paris doing translating work, making himself useful, for example, to the leading French astronomers J.-N. Delisle and Charles Messier by seeking out Portuguese astronomical observations and then translating them into French. It is not clear what he was living on: he had a small income from Aveiro, he presumably was paid for at least some of the translating he did (e.g., a Portuguese version of the standard Greek grammar used at Port-Royal in Paris), perhaps he also did some tutoring. He thought about going to Italy or America but eventually settled in London, in late 1763, where he gradually established a network of contacts within the British scientific community.[21]

Magellan's strategy here is very interesting. As a foreigner, it could have been no easy matter to establish himself within London society. Presumably, however, he had brought with him introductions from the French astronomers with whom he had

[19] *VE*, I, pp. 292-3.

[20] Magellan and Volta wrote to each other in French. The originals of most of Magellan's side of the correspondence are held by the Istituto Lombardo in Milan (*Cart. Volt.*). These have been published already, in the National Edition of Volta's correspondence. However, the texts that have been published are not complete in all cases, and also the transcriptions contain many errors, most of a relatively minor kind but some that are quite significant.

[21] For further details about Magellan, see I. MALAQUIAS, *A obra de João Jacinto de Magalhães no contexto da ciência do séc. XVIII*, PhD thesis, (Universidade de Aveiro, 1994).

become acquainted – Delisle, Messier, above all the Chevalier de Bory, whom he had assisted when the latter visited Portugal in 1753 and who remained an important friend thereafter. These he used to gain access to the meetings of the Royal Society, which he proceeded to attend exceedingly regularly as a guest of one or other of the Fellows. And this, of course, gave him contact with other Fellows. He also submitted a number of minor papers to be read at the Society's meetings, and passed on the latest astronomical news from his correspondents in Paris – especially Messier. His own papers were usually on questions of instrument design, at first chiefly in relation to barometers. Eventually, in 1774, he was himself elected a Fellow of the Society.

Meanwhile, Magellan also cultivated his correspondence, which in the course of the following two decades grew to immense and extraordinarily wide-ranging proportions. At first, this was chiefly with his Portuguese contacts and with the French, not just with the astronomers but also with the chemists, with important consequences. He was, for example, the principal channel by which the French learned of the work of Black, Cavendish, Priestley and others on gases, inspiring Lavoisier to take up the subject with epoch-making results.[22] Some years later, it was Magellan who told the French about the work of Black, Irvine and Crawford on specific and latent heats – he it was, indeed, who coined the term "specific heat" – leading to the important work of Lavoisier and Laplace on this topic. His network expanded to Berlin after he met Johann III Bernoulli when Bernoulli visited London in the late 1760s, and to Belgium, which he visited regularly. Often, he began a correspondence on his own initiative, as he did with the St. Petersburg Academy of Sciences[23] and as he seems to have done in the case of Volta.

Why did he bother? He had, it seems, struck upon a novel way of making a living, one that fitted perfectly with his own interest in and enthusiasm for science. The fact that he was in London, the centre of the world's scientific instrument trade at the time, was also relevant, and his settling there no accident. In fact, Magellan appears to have made a living from his correspondence. In his letters, he brought to the attention of those to whom he was writing the latest developments in British science – the latest publications, the latest doings at the Royal Society, and also the latest developments in the scientific instrument market. Then he served as an agent, supplying to his many correspondents the books and instruments they requested. In doing so, he doubtless received – most discreetly, of course, so as not to infringe upon his status as a gentleman – commissions from those with whom he placed the

[22] H. GUERLAC, *Lavoisier – the Crucial Year: The Background and Origin of his First Experiments on Combustion in 1772*, (Ithaca, N.Y., 1961), chap. 2.

[23] R.W. HOME, "Scientific Links between Britain and Russia in the Second Half of the Eighteenth Century", in A.G. CROSS, ed., *Great Britain and Russia in the Eighteenth Century: Contacts and Comparisons*, (Newtonville, Mass., 1979), pp. 212-24; reprinted in R.W. HOME, *Electricity and Experimental Physics in Eighteenth-Century Europe*, (Aldershot, Hampshire, 1992), XVIII, pp. 212-24.

orders. As the journalist J. P. Brissot reported, having met him in London, "by making himself the correspondent of savants everywhere, ... he achieved an honourable independence".[24]

This, then, is the context in which we must view Magellan's correspondence with Volta. But let me emphasize again how wide-ranging his correspondence was generally. It included not only a number of leading French scientists but Bernoulli, Achard and Bode in Berlin, Bergman in Uppsala, Nathaniel Wolf in Dantzig, Ingenhousz in Vienna, the botanist Spielmann in Strasbourg, the astronomer Christian Mayer in Mannheim, the Prince-Bishop Massalski in Poland, van Swinden and van Marum in Holland, the Abbé T. A. Mann, the expatriate English astronomer Nathaniel Pigott and the Duc d'Aremburg in Brussels, Lexell and Euler *fils* in St Petersburg, Saussure and Mallet in Geneva. He became a corresponding member of not only the Paris Academy of Sciences but also the Academies in St. Petersburg, Lisbon, Brussels and Madrid; and he was clearly acting in at least a semi-official capacity on behalf of the Academy in Berlin. All of them he supplied with information, and with books and instruments on demand. In Italy, he was corresponding regularly with Marsilio Landriani in Milan, with Giovanni Fabbroni in Florence, and with the Academy of Sciences in Turin, as well as with Volta. There is no central archive of Magellan's letters and papers, but over 700 letters to or from (mostly from) him survive, scattered in libraries and archives across Europe and North America.[25]

Apart from the inscription he wrote in the copy of Priestley's book, the first substantive letter from Magellan to Volta that survives was dated 27 October 1778.[26] It accompanied a copy that Magellan sent to Volta of a bill of exchange he had drawn that day on Volta's account, to cover the purchase of apparatus Volta had ordered and which Magellan had just seen shipped to Genoa. Three boxes had been sent: Magellan detailed what they contained, together with what he had paid for each item. On this occasion, most of the apparatus was for experimenting with gases. Volta had been appointed shortly before to the chair at Pavia, and some items Magellan sent were clearly intended to be used in up-to-date demonstration experiments accompanying Volta's lectures. Other items, equally clearly, were intended for research. From another letter written soon afterwards, we learn that some of the items shipped initially had been incomplete and that Magellan was sending a parcel containing the missing bits to Milan, in a box addressed to Marsilio Landriani – Magellan was a past master at using the diplomatic mails whenever the opportunity offered – who would no doubt pass them on to Volta. Magellan, we

[24] J.P. BRISSOT, *Mémoires (1754-1793)*, C. PERROUD, ed., (Paris, 1911), I, p. 363.
[25] Together with colleagues in Portugal, I am currently editing these letters for publication.
[26] This letter was not included in Volta's published correspondence. I am grateful to Alessandra Ferraresi for furnishing me with a copy of it.

discover from this letter, was also supplying instruments to Landriani on a substantial scale.[27]

In characteristic fashion, Magellan, in the second of these letters to Volta, also told the Italian about the new machine invented by Atwood to demonstrate the laws of motion. Atwood, he reported, "is an excellent mathematician, and possesses an extraordinary talent for rendering the most abstract phenomena sensible in experimental practice". Just the previous day, Magellan told Volta, he had taken his friends Priestley and Richard Price to see the new machine, and they could not have been more impressed: "the simplicity of the machine ... and the exactness (*justesse*) of the experiments are astonishing". Atwood was about to publish a treatise on rectilinear and rotatory motion that would include a description of the machine.[28] He had also issued a prospectus for a four-volume "complete course of experimental physics" that Magellan thought would be "the most complete and the most instructive" of its kind: Magellan had taken the liberty of entering Volta as a subscriber for this. (The work was in fact never published). Sure enough, Volta wanted one of Atwood's machines for himself, and succeeding letters detail Magellan's supplying of this.[29] He also supplied many other demonstration pieces – some very expensive, but Volta had been given an almost unlimited budget for this purpose. They included an orrery to demonstrate planetary motion, microscopes, an apparatus to demonstrate the refraction of light, burning lenses, a "pneumatic machine" (that is, an air pump) by Nairne that cost £40, one of the latest frictional electrical generating machines by Adams, and a telescope by Ramsden.

Other items supplied were clearly intended to support Volta's research rather than his teaching. I have mentioned the special glassware for experiments on gases. Later, Magellan had parts made for Volta's eudiometer, though the makers experienced great difficulty in making uniform, properly calibrated cylinders. He also supplied barometers and – a sign here of Volta's growing habit of quantitative rather than merely qualitative experimentation – a standardized, one Troy ounce weight and a standard ruler calibrated in both English and French measures.

In addition to equipment, over the supply of which Magellan took great pains, including constant supervision of the makers and a detailed inspection of the final product, he sent books and information. The new theory of heat due to Black and Irvine is a major theme of the letters, focused particularly on Adair Crawford's well-known book first published in 1779,[30] a copy of which Magellan promptly supplied to Volta. The dissemination of these ideas was something to which Magellan

[27] *VE*, I, p. 339.
[28] Atwood's treatise was in fact not published for several years; cf. G. ATWOOD, *A Treatise on the Rectilinear Motion and Rotation of Bodies; with a Description of Original Experiments relative to the Subject*, (Cambridge, 1784).
[29] *VE*, I, pp. 378, 389.
[30] A. CRAWFORD, *Experiments and Observations on Animal Heat, and the Inflammation of Combustible Bodies*, (London, 1779).

himself contributed in a more substantial way by sending a report of his own on the subject to Paris for publication in Rozier's journal; this seems to have been instrumental in attracting Lavoisier and Laplace to the subject, leading to their famous collaboration in 1783 with an ice calorimeter.[31]

Volta's correspondence with Magellan was thus very rewarding from Volta's point of view. It gave him, at last, the dependable link with English science that he had earlier been hoping to achieve through his correspondence with Priestley. There is no doubt that Volta felt very isolated in Italy, and he clearly welcomed and came to rely heavily on his contact with Magellan. It is surely no accident, however, that the contact blossomed when it did. There is likewise no doubt that it was very rewarding from Magellan's point of view as well. Following Volta's move to Pavia in 1778, he urgently needed help in spending the large sums of money that had been put at his disposal to furnish his new institute. The Austrian Government wanted his department to become a showpiece of its enlightened administration of its Italian territories, and Magellan was ideally placed in London, in daily contact with the leading scientific instrument makers of the day, to ensure that their money was well spent. Moreover, he had positioned himself precisely to provide services of this kind. The superiority of London's scientific instrument makers had created an opening and he had seized it – driven in part, no doubt, by financial considerations, but chiefly I believe by an often expressed and genuinely held sense of moral obligation, to disseminate the fruits of scientific enlightenment in order to improve mankind's lot.

Meanwhile, Volta continued to pursue other strategies as well, to overcome his isolation. Just as his correspondence with Magellan was beginning to open up, he also tried to establish an alternative connection with the British scientific community, through the British nobleman and scientific enthusiast, the 3rd Earl Cowper, who was living in Florence at this period (and who was another correspondent of Magellan's). Cowper sent news of Volta's work on inflammable airs, and on the capacity of electrical conductors, to the Royal Society, of which he was a Fellow. His proposal that Volta be elected a foreign member of the Society , however, fell foul of a recent decision by the Council of the Society to put a temporary freeze on the election of any further foreign members.[32] Volta's work was also being discussed in Brussels, as a result of his sending some of his papers to the scientifically inclined Prince Charles of Lorraine, regent of the Austrian

[31] *Observations sur la physique*, 17 (1781), pp. 375-86, 411-22; also separately published in London a few months earlier as Magellan, *Essai sur la nouvelle théorie du feu élémentaire, et de la chaleur des corps*, (London, 1780). On the influence on the French of Magellan's communications, see R. FOX, *The Caloric Theory of Gases from Lavoisier to Regnault*, (Oxford, 1971), p. 29, and H. GUERLAC, "Chemistry as a Branch of Physics: Laplace's Collaboration with Lavoisier", *Historical Studies in the Physical Sciences*, 7 (1976), pp. 230-4.

[32] *VE*, I, pp. 260-1, 281, 294, 299-300, 302-3, 308-9, 312, 335-6, 341; *VO*, VI, pp. 235-40.

Netherlands.[33] In addition, Volta renewed his efforts to establish contacts with French science by sending brief summaries of his work on inflammable airs to Rozier in the first months of 1777, in the hope that the latter would publish them in his journal.[34] Not until over a year later, however, after Volta's experiments had been successfully repeated before the Académie Royale des Sciences in March 1778, did Rozier publish an account of the work.[35] Later that year, as we have seen, Rozier also published Senebier's translations of two of Volta's papers.

By the late 1770s, therefore, Volta had at last arrived at the point where he had a reliable link to English science, and his work was beginning to find regular exposure in Paris. He must, however, have been all too aware of the fragility of the connections he had established, and of the need to cement them more securely. Beginning in 1777 with a visit to Switzerland, during which he made important contacts in Geneva with Senebier and Horace-Bénédict de Saussure, and in Strasbourg with Barbier de Tinan, who soon afterwards was instrumental in making his work on inflammable gases known in Paris, Volta looked to travel, and the personal interactions that would result, as a means of strengthening his position. A visit to Florence in 1780 brought him into closer contact with Earl Cowper, whom Volta continued to consider as a means of bringing his work before the Royal Society. Volta saw many pieces of apparatus that were new to him during this trip. On returning to Pavia, he obtained authorization to place large orders in both London – where Magellan naturally took matters in hand – and Paris, where Sigaud de la Fond was the intermediary. Then, in 1781/2, Volta was abroad for almost a year, chiefly in Paris, in other cities in northern France such as Strasbourg, and in England.

During this trip, Volta met Magellan in person for the first time, and the contact between them contributed crucially to the success of Volta's trip as a whole. The Portuguese seemed to know everybody and, as a result, was able to open doors everywhere for his Italian colleague. Magellan was in Brussels – which he visited frequently – when Volta first arrived there, and the two men toured Holland together, before Volta settled in Paris for several months.[36] Then, when Volta was ready to move on to England, the two met up again in Brussels and travelled to London together. There Magellan at once introduced Volta to his scientific friends and to the President of the Royal Society, Sir Joseph Banks – this being a necessary preliminary to Volta's attending meetings of the Society as Magellan's guest and presenting his latest work on electricity.[37] Magellan and Volta seem to have got on extremely well – so well, indeed, that they then undertook an extensive tour together

[33] *VE*, I, pp. 169-70.
[34] *VE*, I, pp. 158-9.
[35] *VE*, I, pp. 229-30; *Observations sur la physique*, 11 (1778), p. 401.
[36] *VE*, II, pp. 65, 68-9.
[37] *VE*, II, pp. 98-9, 103-4.

of the new manufacturing centres in the English Midlands.[38] There is a new warmth to their letters after this time that obviously reflects the personal friendship they had established. The one letter we have from Volta to Magellan is from a year or so after their travels together, and fits into the pattern. Volta thanks Magellan for his "literary news", which he has shared with various acquaintances, and urges Magellan to keep up the flow. He sends news of his own, and warm greetings to Crawford and Richard Kirwan, two other friends he had made while in England; and he offers some derogatory remarks about the French claims concerning the novelty of Montgolfier's famous experiments with manned balloon flights. All that Montgolfier had done, Volta assured Magellan, was develop the technology needed to put into effect, on a large scale, suggestions that he himself had been making in Paris and elsewhere, months before.[39]

This letter also reveals another hazard confronting people such as Volta, who were dependent on specialist instrument makers elsewhere; for one of the shipments sent by Magellan had been captured by the Spaniards, who were at war with England at the time! Because Volta's purchases were official ones – on behalf, technically speaking, of the Austrian government – Volta had been assured that they would be released in due course. Nevertheless, there was a delay of several months before he was able to use them.

The last letter we have in this fascinating sequence is dated October 1785. Doubtless there were others afterwards but probably not very many because Magellan was suffering from persistent ill-health in the later 1780s, and for the last year of his life – he died in February 1790 – he was a hopeless invalid (indeed, from the descriptions we have, it sounds as though he had a stroke of some kind that left him incapacitated).

As might perhaps have been expected, a consistent theme in Magellan's last few letters to Volta is the rise of Lavoisier's new chemistry; this of course being a feature of science in the 1780s. Magellan, influenced no doubt by his friends Priestley and Kirwan, remained for some years an adherent of the phlogiston theory. First, Magellan reported to Volta the famous experiments on the composition of water that he interpreted, following James Watt, as showing that water was a compound of dephlogisticated air with phlogiston. The French, too, he sourly noted, according to their custom, pretended to have discovered this after having been informed of it. (Volta, he knew, would appreciate such a comment).[40] In a subsequent letter, Magellan reported how Kirwan was preparing a refutation of some Lavoisier-inspired work by one of Joseph Black's students in Edinburgh.[41] But in his final letter, Magellan seemed to see the writing on the wall. Though neither

[38] *VE*, II, pp. 471-3.
[39] *VO*, VI, pp. 319-23.
[40] *VE*, II, p. 216.
[41] *VE*, II, pp. 291-3.

Kirwan nor he himself could see any solid basis to Lavoisier's ideas, the tide seemed to be running the latter's way. Berthollet, Magellan had been informed, had converted. The dream of the great Stahl was going to lose its empire, he feared – as indeed it did, shortly afterwards.[42] By the late 1780s, Magellan himself had switched sides.

3. Aftermath

From what has been said, it will be evident that we do not find, in the series of letters between Magellan and Volta that have been discussed here, detailed insights into the evolution of Volta's scientific ideas (or Magellan's, for that matter). In Volta's case, there are simply not enough letters to be revealing at that level. The letters do, however, provide many insights of other kinds into this period of Volta's scientific career. In particular, we can see how they helped him overcome his isolation by providing him with a constant stream of news and scientific gossip. Whereas in his early years he was clearly working in ignorance of what others were doing – hence his claiming so many discoveries that were not in fact new – in later years, thanks to correspondents such as Magellan, he had a much clearer idea of who was doing what. To be sure, the line of communication was interrupted from time to time, when letters went astray or Magellan's persistent migraines got to be too much for him and he had to stop writing for several months at a time. Of course, in time Volta got to know others too – especially following his journey of 1781/2 – to whom he could write. But Magellan had one great advantage as a person with whom to correspond: he could be depended upon, for his own reasons, to keep on writing. Others among Volta's correspondents were far less reliable in this respect. And reliability matters if you are depending on your correspondents to keep you up to date, so that you do not have to rely on published reports that might not come out until months or even years after the event, or remain in ignorance of important new items of equipment. And so, for several years, Volta came to depend on his correspondence with Magellan, very much. It is also, however, the case that by the mid-1780s, when Magellan wrote his last letter to Volta that has come down to us, Volta was much better connected to the international scientific community than he had been only a few years earlier, and correspondingly less dependent on links with any particular individual. He was now personally known to and respected by most of the leading English scientists of the day, so that any discoveries he communicated to them would be taken seriously. Supplementing his correspondence with Magellan, he exchanged letters regularly for a time with the Swiss physicist Jean André de Luc, who was living in England at this period and who had undertaken to prepare an account, subject to Volta's scrutiny, of the latter's ideas on electric

[42] *VE*, II, pp. 316-7.

atmospheres.[43] As a result of De Luc's dithering, however, this project ultimately came to nothing.

On 5 May 1791, Volta was at last elected a foreign member of the Royal Society of London.[44] Thereafter, formally speaking, he no longer had to depend on someone else to report his work to the Society, he himself could report it directly. This no doubt encouraged him to look more often to the Society as the preferred venue at which to announce his discoveries. Even so, when in the early 1790s he wished to report his initial investigations challenging Galvani's interpretation of his experiments on "animal electricity", as a matter of convenience he at first relied on the expatriate Neapolitan physicist Tiberio Cavallo to communicate his papers to the Society. Unfortunately, this led to some confusion as to whether he had intended his material for publication, leading Banks to write asking him in future to send his material directly to the Secretary of the Society.[45] There could be no stronger indication, surely, of Volta's changed status – a change that was to be reiterated another year on, when the Society awarded him its most prestigious prize, the Copley Medal for 1794.[46]

It was thus no accident that when, in 1800, the Italian, Volta, came to announce his epoch-making discovery of the electric pile, he chose to send his paper right across Europe, to the Royal Society of London, for publication, rather than publishing it at home. Then, as earlier, the structure of the scientific community was such that, if the discovery were to have an impact, it was essential that it be noticed by those working at scientific Europe's leading "centres of calculation". But now, thanks to his earlier contacts with Magellan and others, Volta enjoyed unfettered access to English science and so could at last be sure that, if he had good work to report, it would indeed be noticed. And it was!

[43] *VE*, II, pp. 162-6, 181, 196-200, 203-9.
[44] Volta's nomination certificate was signed by Edward Whitaker Gray, Charles Blagden, George Fordyce, Alexander Aubert, Anthony Shepherd, Jesse Ramsden, James Edward Smith and Edward Nairne.
[45] *VE*, III, pp. 203-4.
[46] *VE*, III, p. 239.